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Aerodynamic Noise Research Support  
For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
GEORGE C. MARSHALL SPACE FLIGHT CENTER  
HUNTSVILLE, ALABAMA

ATTENTION PR-EC

June 30, 1966

During the present quarter, work has been completed in the theoretical study of shock turbulence interactions. A report on this study,

"The Fluctuating Pressures Due to Shock Interactions with Turbulence and Sound",  
Wyle Laboratories Research Staff Report WR 66-35,  
is enclosed <sup>separately</sup> ~~herewith~~. This report formed the basis of a paper given by the project manager at the Seventy-First Meeting of the Acoustical Society of America in Boston, Massachusetts, 3 June 1966. The paper caused some interest, and several requests for the report have been received.

The theoretical study predicts that fluctuating pressure levels of over 170 dB could occur due to interaction of intense wake turbulence, for instance from the escape tower with a typical separation shock and also indicates levels of well over 160 dB for the peak fluctuating pressure immediately beneath a typical separation shock. The potential significance of such levels is clear and Appendix A to this progress report gives an outline of an experimental program designed to substantiate and extend this theory. The execution of such a program appears to be very desirable.

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Further work at Wyle Laboratories during this quarter has involved the study of low speed separated flows using a special section of Wyle Laboratories low speed wind tunnel. Mean velocity profiles have been measured at a number of stations. However, some unexpected results were obtained and work is at present aimed at determining how realistic these results may be. The experimental work on low speed separated flows will continue during the coming quarter.

The completion of the study of unsteady supersonic separated flows in the Marshall Space Flight Center seven inch wind tunnel has been delayed because of difficulties in obtaining a suitable high speed camera. However, relatively high speed motion pictures taken at Marshall Space Flight Center have revealed some interesting features of the unsteady flow which will be the subject of a report after the experiments are complete.

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## APPENDIX A

### SUGGESTED EXPERIMENTAL PROGRAM ON SHOCK-TURBULENCE AND SHOCK-SOUND INTERACTIONS

#### Background

A recent report (Reference 1) has demonstrated the potential significance of shock interactions in the production of buffet loadings on launch vehicles. The theory presented in that report indicates that fluctuating pressure levels over 170 dB could occur due to the interaction of the escape tower wake turbulence with a separation shock. Even in the absence of this wake the theory predicts surface pressure fluctuation levels beneath typical separation shock to be well above 160 dB. It therefore appears that shock turbulence interaction phenomena are of major practical importance.

Reference 1 also demonstrates the amplification of sound waves by a shock and suggests that the shock wave may couple to vehicle or local panel motion to produce large levels of fluctuating pressure at the surface. The amplification of sound waves can be important in the interpretation of wind-tunnel tests where wind-tunnel noise is present, and the possible coupling action of the shock with panel motion would lead to resonant panel response which could well cause failure.

It therefore appears that shock interaction effects can be of considerable practical significance, and this note outlines an experimental program for investigation of the phenomena.

#### Approach

Pressure fluctuation measurements should be made on a surface immediately behind a shock wave, while the shock is undergoing various interactions.

In order to achieve maximum experimental simplicity, the rig shown in Figure 1 is recommended. It consists of a flat plate, with a chamfered leading edge, capable of being mounted at various angles of incidence to the flow. A shock wave will then form in front of the plate with strength dependent on the angle of incidence

and free stream Mach number. This is the shock which will be used in the interaction study.

First the amplification of sound waves by a shock will be studied. The sound must be initially measured in the absence of the shock wave. Either the basic wind tunnel noise or a special upstream siren could be used as the sound source. Then the plate and associated shock wave would be introduced into the flow and the sound level at the plate recorded under various combinations of incidence and Mach number. In principle, only the Mach number normal to the shock would be significant, but in practice, some secondary dependence on other parameters might be expected.

After this study, shock-turbulence interactions would be investigated. Initially, a turbulence generating device must be made and its downstream turbulence field measured. It is thought that the wake from a simple structure consisting of a number of small flat plates randomly oriented to the flow would be effective here. Alternatively, a series of small jets could be used. Turbulence in supersonic flow consists of three modes: vorticity, entropy, and sound. Determining the actual contribution of each mode will require a hot wire survey run at various temperatures (see Reference 2). Once the exact contribution of each mode is defined, the pressure fluctuation levels due to the total shock turbulence interaction can be predicted from Reference 1. Note that these experiments could be performed in a medium size wind-tunnel - say 2 to 3 feet in section, and realistic results could be anticipated. The actual dimensions for the test items would be determined by the tunnel used.

#### Further Experiments

A number of additional experiments may also be justified at this time.

The effect of the axisymmetric shock interaction typical of space vehicles is of interest. The possible focussing effects of a conical shock interaction could be significant. A suitable experiment would follow the same general lines as above, but use a conical body.

Measurements of the turbulence level immediately in front of a shock-boundary layer interaction would indicate the significance of the shock-turbulence interaction on the peak pressure fluctuation. This test could be combined with the use of artificially thickened boundary layers to give further insight into the mechanisms at work in this case.

Finally, the possibilities of shock-panel motion coupling are definitely of practical interest. A program would involve the generation of a shock at various stations along a panel as shown in Figure 2. The panel would then be excited and the input impedance measured at various frequencies. If there is significant excitation from the shock, then the input impedance would be reduced greatly and the response increased - possibly to the point of instability. The practical significance of such effects is clear.

### Conclusions

It has been shown that the pressure fluctuations due to shock interactions with turbulence and sound can be of distinct practical significance. An experimental program to substantiate and extend this theory is therefore recommended.

The results from the study will facilitate engineering prediction of the significant surface pressure fluctuations in complex supersonic turbulent flows, particularly for the effects of the turbulent wake from the escape tower and other protuberances. The complete program will also define the mechanisms causing pressure fluctuations beneath shock waves, and the significance of shock wave feed back in panel response problems.

### References

1. Lowson, M.V., "Fluctuating Pressures due to Shock Interactions with Turbulence and Sound", Wyle Research Report WR 66-35, June 1966.
2. Kovasznay, L.S.G., "Turbulence in Supersonic Flow," J. Ae. Sci., Volume 20, pp. 637-675, October 1953.

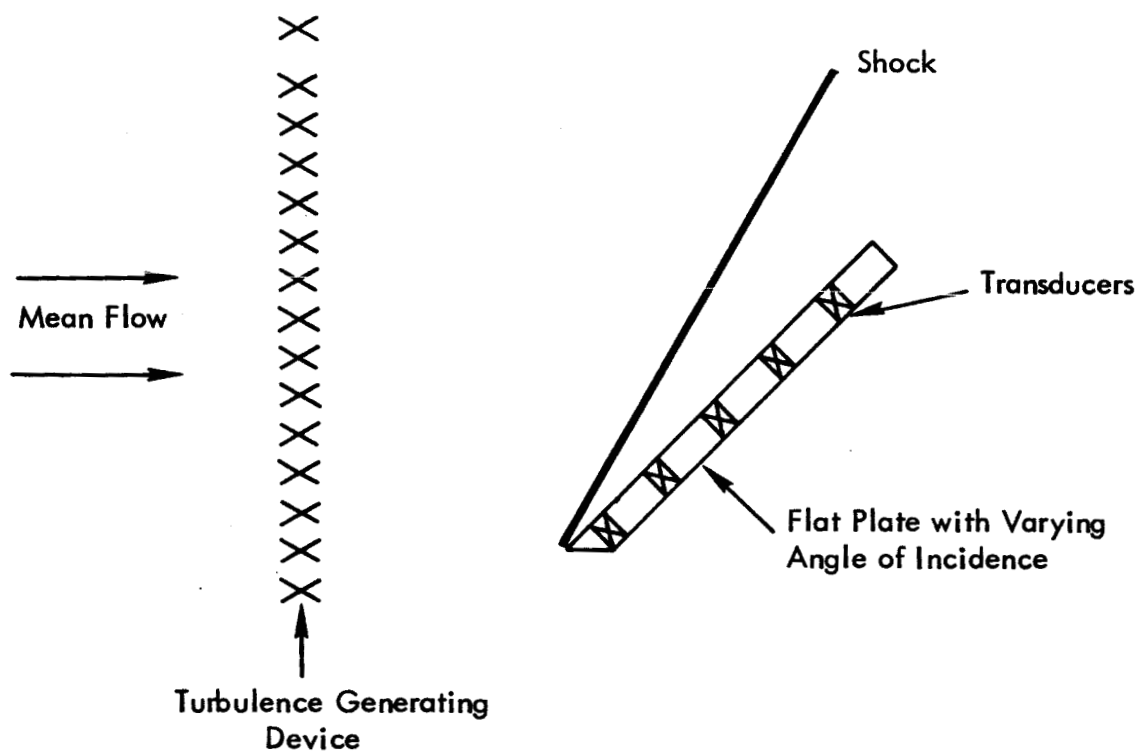


Figure 1. Suggested Experimental Rig for the Investigation of Shock-Turbulence and Shock-Sound Interaction

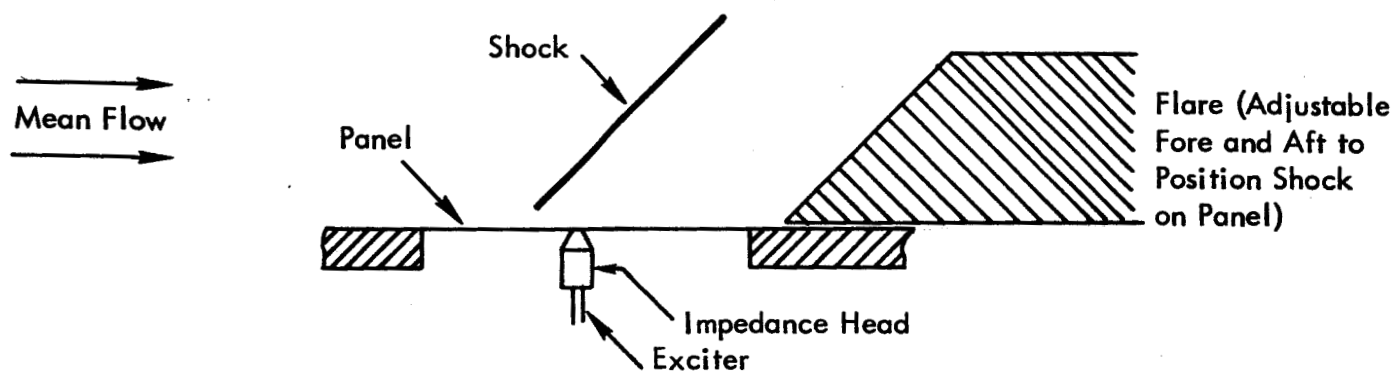


Figure 2. Suggested Experimental Rig to Investigate Shock-Panel Coupling Effects